

REVISION OF SCIENTIFIC OBJECTIVES  
FOR PARTICIPATION IN THE VOYAGER MISSION

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Almost all of the objectives in my original proposal (8/19/72) remain a valid line of attack, and several new objectives have presented themselves in the interim. The following is a short summary, without literature citations, of these objectives.

(1) Examination of chromophores in the atmospheres of Jupiter and Saturn

Jupiter and Saturn clearly show heterogeneous time-variability in coloration down to the highest resolutions available. In their recent analysis, Sagan and Salpeter have shown that the chromophores preferentially reside at the 220°K or deeper levels of the Jovian atmosphere and have discussed a range of possible production mechanisms. Chromophores being advocated today include organic molecules, polymeric sulfur,  $\text{H}_2\text{S-NH}_3$  interaction products and elemental phosphorus. Fortunately, many of these candidate materials have different broad-band spectral properties in the visible, ultra-violet and infra-red. For example, an analysis of ground-based observations by Rages and Sagan shows that a mixture of laboratory organics and sulphur matches the reflectivity data far better than either alone. High spectral resolution observations of the Jovian and Saturnian clouds in color may be able to distinguish among the various candidates. There is every reason to think that the distribution of optical-frequency chromophores will continue to be heterogeneous when the resolution exceeds the best ground-based resolution, and it is entirely possible that the distribution of small colored spots, bands and belts over the disc of Jupiter will provide clues on the nature, the depth of generation and the significance of the observed lateral distribution of coloring material. An extensive library of laboratory spectra -- particularly of a wide range of organic solids produced in simulated Jovian conditions -- is being accumulated to compare with the Voyager observations. It is also proposed to correlate the positions and time evolution of optical-frequency chromophores discovered by the imaging experiment with the time histories and distribution of absorbers discovered by the ultra-violet and infra-red spectroscopic experiments on Voyager.

(2) Search for night-side fluorescence, airglow and auroral activity

Auroral signatures of the dumping of high-energy charged particles from the Jovian Van Allen belts may be expected. The locales of dumping, particularly the radiation belt mirror points, should be sites for the preferential production of organic molecules in the region of the Jovian atmosphere. Such regions can be examined in daylight for optical-frequency chromophores and possible ultra-violet and infra-red spectroscopic signatures of organic molecules. Such research would be coordinated with particles and fields experiments on Voyager.

(3) Observations of vorticity and exchange in the Great Red Spot

In a 1971 critical survey, six quite different models of the Great Red Spot (GRS) of Jupiter were listed. One of the most hardy of these is the Taylor Column hypothesis of Hide, in which the GRS is postulated to be the top of a stagnant Taylor Column anchored over some discontinuity in the lower atmosphere or surface. In the original version of this hypothesis, the GRS is purely barotropic and absolutely stagnant. Nevertheless, some ground-based reports exist in the literature of vorticity within the GRS and exchange of material between the GRS and its surroundings, which, if true, would contradict this formulation of the Taylor Column model. In addition, the question of exchange is very important because if chromophores are not pouring into the GRS and are not produced from above, they must be welling up from below -- which implies that the GRS coloration is typical of that of the more inaccessible lower clouds of Jupiter. Study of the GRS is as important, for example, as study of the North Equatorial Belt for testing hypotheses of chromophore nature and origin. Other high resolution observations of the dynamics of the GRS can serve to test other models of the GRS; for example the Cartesian diver model of Sterett, et al. predicts a counter-current in the interior of the GRS. The lifetime of material leaving the GRS may also give information on the chromophore composition.



(4) Examination of the satellites of Jupiter and Saturn

There are 24 or so known satellites of Jupiter and Saturn. Some of them are clearly of planetary dimensions; others are almost certainly small captured asteroids or comets. Even with the extremely limited ground-based resolving powers now available, it is clear that these satellites differ enormously in density, albedo, albedo variation, and color. Even if we were unable to specify specific experiments, the existence of the observatory capability of Voyager suggests that the scientific harvest will be very rich. Some of these satellites have very low densities, suggesting they are made largely of condensed volatiles. As pointed out by Lewis, radioactive decay in the rocky volatile-rich satellites should produce sub-surface melting. Are there surface geological constructs on these objects which are the icy equivalent of lava constructs on the terrestrial planets? Will there be evidence for glaciation, pingoes, sinuous channels? If the latter are present, analyses just being developed at Cornell which successfully predict the branching ratios of terrestrial and martian channels can be applied. Will impact melting soften the contours of impact craters which would thus be self-healing? The distribution of polar frosts can provide phase-change isotherms, which can be used to determine the chemical composition of the frost and something of the thermal and electrical properties of the sub-surface material. There is now a wide range of evidence for albedo variation of these satellites, perhaps the most striking of which is the trailing/leading hemisphere differences on Iapetus. Does this also correspond to significant color and morphological differences? In some versions of the sputtered evaporite model of the Io cloud, ancient seas are postulated. Are evaporites preferentially present in basins? Recent work with the RATAN-600 radio telescope in the Soviet Union imply that J2, J3 and J4 have thermal microwave emissions, while J1 has an enormously high brightness temperature. This is conceivably due to the thermalization of Van Allen Belt particles at Io. Do the colorimetric properties of J1 and J5, and their photometric and polarimetric properties match that of radiation-damaged minerals

and the resulting F-centers? Will high resolution observations of Io just after eclipse confirm the reported post-eclipse brightenings? Can we confirm the "morning haze" reported by Lyot on Ganymede? High resolution photography of satellite shadows on Jupiter and Saturn can be used to determine atmospheric structure and possible elevation differences between cloud decks. Since some reports exist of variable features on the Galilean satellites, the Mariner 9 and Viking variable features protocol -- depending on the relative constancy of the three photometric angles -- should be used. Do the polar regions of the Galilean satellites show laminated terrain as on Mars? Why, as some observations suggest, do the three outer satellites have bright polar regions and dark equatorial belts, while Io has dark polar caps and white equatorial regions? Can the progressive changes in spectral reflectivity with distance from Jupiter be explained in terms of Van Allen belt irradiation? Can the distribution of chromophores over the discs of these satellites give information on locales of outgassing?

Titan is a major objective of the Voyage mission. Recent work at Cornell using combined ultra-violet, visible, infra-red, and microwave data, plus the lunar occultation results on the diameter and limb darkening of Titan, have significantly narrowed the range of possible atmospheric models. Voyager observations can make major additional progress, especially with cross-correlation of imaging, ultra-violet, infra-red and microwave occultation experiments. We are interested in a detailed study of color distribution and the search for cloud motions in its atmosphere; an analysis of optical chromophores comparable to that proposed for Jupiter and Saturn; a search for breaks in the clouds and surface morphology; limb darkening as a function of wavelength to obtain atmospheric parameters; the exact radius; and the optical oblateness. Long wavelength observations at the limb may test, through Rayleigh scattering, some models of high atmospheric pressure.

#### (5) Miscellaneous

Reliable calculations of the heat balances of the Jovian and Saturnian satellites cannot be carried out because of the very limited range of



phase angles so far observed. Disk-integrated brightness measurement as a function of phase angle can remove this uncertainty. The Laboratory of Planetary Studies operates a computer controlled precision goniometer which has now amassed a large library of data on the scattering properties of candidate minerals as a function of composition, particle-size and photometric angles. These data are now being used in conjunction with Viking observations of Mars to set limits on proposed martian surface mineralogy, and will be used for the same purpose in studying the airless satellites of Jupiter and Saturn. Among the more speculative possibilities which I propose to investigate are the application of computer program "Acrete" to high-resolution orbital regularities found in the Saturnian ring system; and a search for the very large isopycnic balloon organisms discussed by Sagan and Salpeter in their analysis of possible ecologies on the Jovian planets. In addition, judging from past experiences in spacecraft missions, there will be many experiments of opportunity connected with the discovery of phenomena entirely unexpected before encounter.

I am taking a leave of absence from Cornell University for the entire calendar year 1979 when I will be based in the Los Angeles area. Apart from a television series which I will be engaged in during this period, almost all my remaining professional time will be directed to the Voyager mission. In particular, I expect to be at JPL for about 45 days around each encounter and to spend a significant amount of time on post-encounter data analysis in the September through December 1979 time frame. One of the graduate students who will accompany me has a substantial background in organic chemistry and is actively engaged in simulations of Jovian and Titanian chromophores in the laboratory. David Pieri, who should have his Ph.D. by the end of calendar 1978, is a planetary geologist of very broad capabilities (having just been offered an assistant professorship in a major geology department while still a graduate student). He will concentrate in particular on the geomorphology of icy and rocky satellites.